ECOSYSTEM STATUS INDICATORS

Groundfish

Trends in Groundfish Biomass and Recruits per Spawning Biomass

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Groundfish that are assessed with age- or size-structured models in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA) show different trends (Figure 65). The assessment information is available in the NPFMC stock assessment and fishery evaluation reports (2004 a, b) and on the web at: http://www.afsc.noaa.gov/refm/stocks/assessments.htm. Halibut information was provided by the International Pacific Halibut Commission (IPHC, S. Hare, personal communication).

BIOMASS

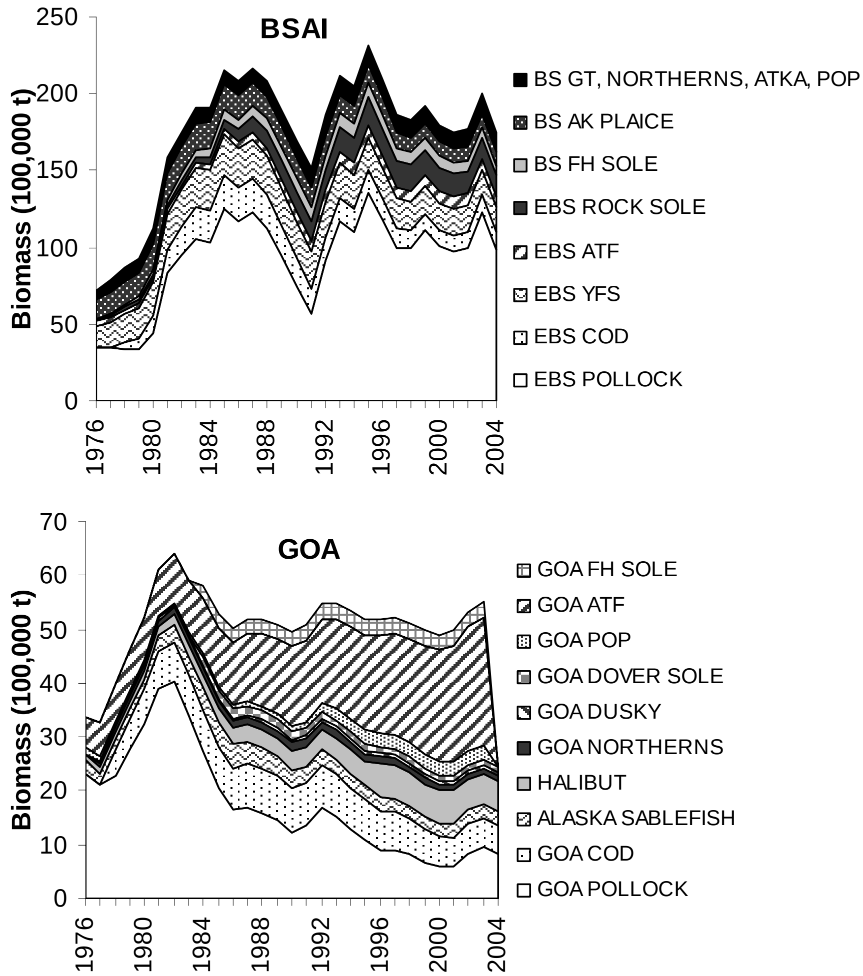

Figure 65. Groundfish biomass trends (metric tons) in the BSAI and GOA from 1978-2004, as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMC (2004 a, b). GOA FH Sole, GOA ATF, and GOA POP biomass time series do not include estimates for 2004. Halibut data provided by the IPHC (S. Hare, personal communication).

Total biomass of BSAI groundfish was apparently low in the late 1970's but increased in the early 1980's to around 20 million metric tons. Some fluctuations in the total biomass have occurred, with biomass below the 1978 to present average occurring in 1978-82 and 1990-91 (Figure 65). Walleye pollock is the dominant species throughout the time series and has influenced observed fluctuations in total biomass.

Gulf of Alaska groundfish biomass trends (Figure 65) are different from those in the BSAI. Although biomass increased in the early 1980's, as also seen in the BSAI, GOA biomass declined after peaking in 1982 at over 6 million metric tons. Total biomass has been fairly stable since 1985, however the species composition has changed. Pollock were the dominant groundfish species prior to 1986 but arrowtooth flounder has increased in biomass and is now dominant. The 2003 IPHC stock assessment of halibut, ages 6 and older, for the GOA (areas 2C, 3A, and 3B) indicates halibut biomass increased from 1978 to 1996 and declined slightly during 1997-2003. Biomass levels in 2003 were still well above the 1978-present average.

RECRUIT PER SPAWNING BIOMASS

Methods

Median recruit per spawning biomass (RS) anomalies were calculated for each species to provide an index of survival (Figures 66 and 67). In stocks that are abundant, the relationship between recruits and spawners will not be linear and density dependent factors may limit recruitment. Under these circumstances, the pattern of recruits per spawner will appear as an inverse of the pattern of spawning biomass as annual rates of production have leveled off. For this reason, it is important to also consider recruitment, as well as recruits per spawning biomass. Recruit abundance of each species was lagged by the appropriate number of years to match the spawning biomass that produced them. For graphical display, the median of each time series was subtracted from the log-transformed recruit per spawning biomass ratios and expressed as a proportion of the median (Figures 66 and 67). A sequential t-test analysis of regime shifts (STARS; Rodionov 2005, Rodionov and Overland 2005) was used to determine if there were significant shifts in the logged recruit per spawning biomass ratios. The STARS method sequentially tests whether each data point in a time series is significantly different from the mean of the data points representing the latest regime (Rodionov and Overland 2005). The last data point in a time series may be identified as the beginning of a new regime; and, as more data is added to the time series, this is confirmed or rejected. Two variables are needed for the STARS method: the cutoff value (minimum length of regimes) and the p-value (probability level). For this analysis, a cutoff value of 10 years and a p-value of 0.10 were chosen. A description of STARS and software is available at: http://www.beringclimate.noaa.gov/index.html. An analysis of recruitment is not included in this section; however, Mueter (this report) examines combined standardized indices of groundfish recruitment and survival rate. Mueter's indices of survival rate are calculated as residuals from stock-recruit relationships, thereby, accounting for density dependence and providing an alternative examination of groundfish survival.

Results

Approximately half the stocks examined displayed a significant shift in RS anomalies in the late 1970s or late 1980's (Table 12). All shifts observed in the late-1980s were negative. Five stocks potentially had shifts in 1998/99 and five stocks showed other or no shifts.

With the exception of a negative 1980-shift in GOA pollock RS anomalies which followed the late-1970s regime shift, roundfish typically did not show the 1976-77 or 1988-89 regime shifts in the BSAI or GOA. Instead, regime shifts were observed in the early to mid-1980s and potential shifts were identified in 1998-2001.

BSAI winter spawning flatfish RS anomalies had a negative shift in the late-1980s, and two of these stocks (flathead sole and rock sole) also had another negative shift in 1994. Similarly, GOA flathead sole also showed a negative shift in 1993. None of the GOA winter spawning flatfish, however, showed the late-1980's shift. BSAI Greenland turbot RS anomalies also showed the negative late -1980s shift. Yellowfin sole, however, shifted in the late 1970s, not the late 1980s. Arrowtooth flounder RS anomalies showed a positive shift in 1969 and a negative shift in 1984.

Rockfish generally showed positive shifts in the late 1970s and negative shifts in the late 1980s. BSAI Northern (positive shift in 1994) and GOA dusky (negative shift in 1999) rockfish were the exceptions.

Conclusions

The survival of roundfish generally did not appear to be affected by the 1976-77 or the 1988-89 climate regime shifts. Examination of the average recruit per spawning biomass anomalies, however, indicates roundfish experience similar trends in survival within ecosystems. For example, pollock and cod have similar recruit per spawner trends within both the BSAI and GOA (Figure 68). Aleutian Island pollock and Atka mackerel (not included in this analysis) also show similar patterns in recruitment (Figure 68; Barbeaux et al. 2003). This may be an indication that roundfish respond in similar ways to large-scale climate changes.

Flatfish survival did appear to be related to known climate regime shifts, especially the late 1980s shift. In particular, the BSAI winter spawning flatfish (rock sole, flathead sole and arrowtooth flounder) show a negative shift in survival in the late 1980s. Examination of the recruitment of winter-spawning flatfish in the Bering Sea in relation to decadal atmospheric forcing indicates favorable recruitment may be linked to wind direction during spring (Wilderbuer et al. 2002; Figure 69). Years of consecutive strong recruitment for these species in the 1980s corresponds to years when wind-driven advection of larvae to favorable inshore nursery grounds in Bristol Bay prevailed (Figure 69). The pattern of springtime wind changed to an off-shore direction during the 1990s which coincided with below-average recruitment.

Rockfish survival also appears to be related to decadal-scale variability since it responded positively to the late 1970s shift and negatively to the late 1980s shift. The mechanism causing these shifts in survival is unknown. Recruit per spawning biomass ratios are autocorrelated in long-lived species, such as rockfish. Results from analyses of rockfish recruits do not show the late 1970s shift.

Table 12. Years and direction of regime shifts observed in groundfish recruit per spawning biomass time series in the Bering Sea/Aleutian Islands and Gulf of Alaska. These are results from the STARS analysis, using a cutoff value of 10 years and a p-value of 0.10. Light-colored text indicates potential shifts near the end of the time series.

Fish Type		Area	Species	Years of regime shifts		
Roundfish		Bering Sea/Aleutian Islands	Pollock	-1983		
			Cod	-1983	1998	
			Atka mackerel	1998		
		Gulf of Alaska	Sablefish	2000		
			Pollock	-1980	1999	
			Cod	-1985	-2001	
Flatfish	Winter spawning	Bering Sea/Aleutian Islands	Arrowtooth flounder	-1989		
			Flathead sole	-1986	-1994	
			Rock sole	-1988	-1994	
	Winter spawning	Gulf of Alaska	Arrowtooth flounder	1969	-1980	
			Flathead sole	-1993		
			Dover sole	1994		
	Other	Bering Sea/Aleutian Islands	Yellowfin sole	-1977	-1984	-1997
			Greenland turbot	-1987	2000	
			Alaska plaice	-1982	1999	
Rockfish		Bering Sea/Aleutian Islands	Pacific Ocean Perch	1975	-1987	
			Northern rockfish	1994		
		Gulf of Alaska	Pacific Ocean Perch	1977	-1989	
			Northern rockfish	-1989		
			Thornyhead rockfish	1980	-1991	
			Dusky rockfish	-1999		

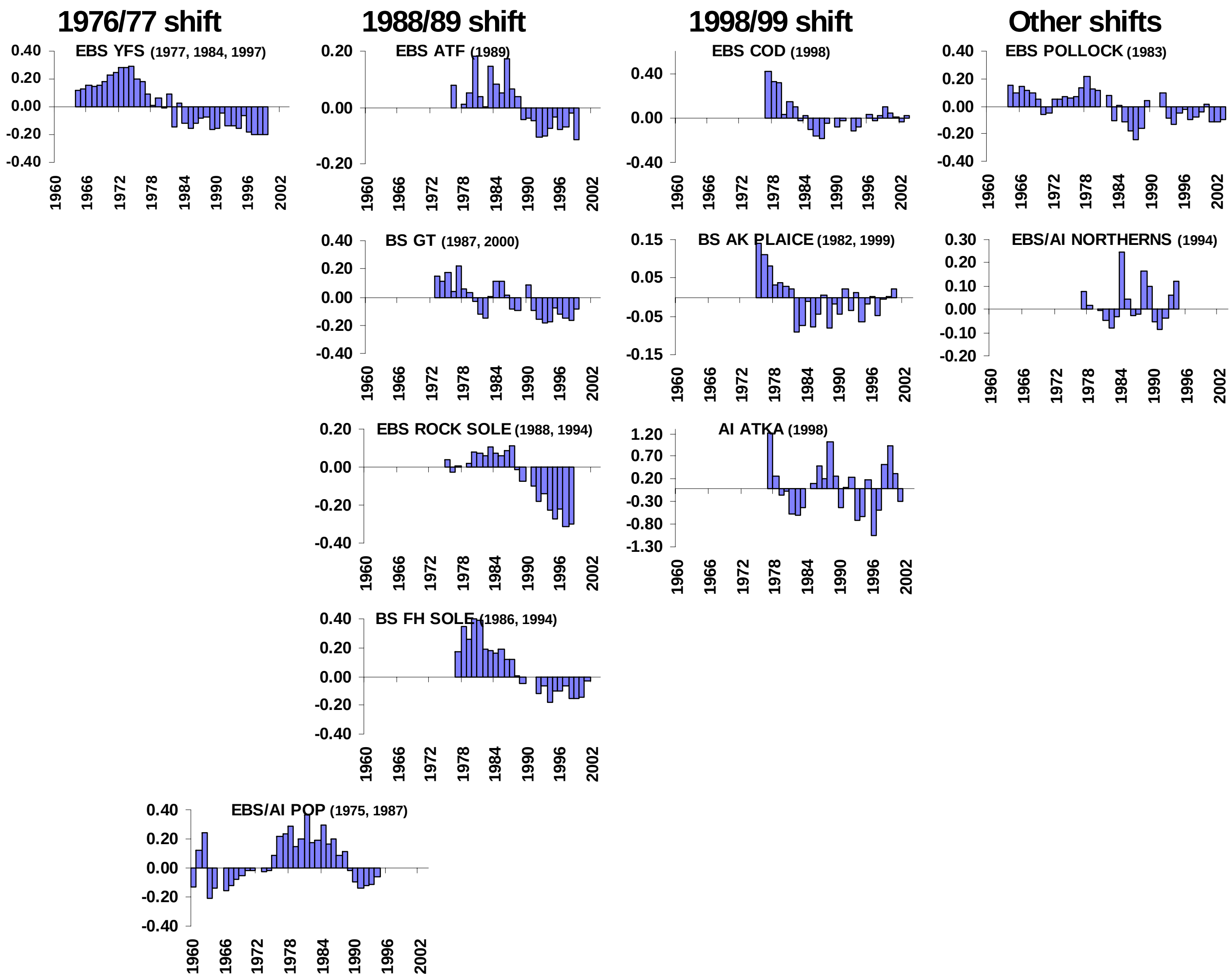

Figure 66. Median recruit per spawning biomass anomalies for BSAI groundfish species assessed with age- or size-structured models, 1960-2003. Stocks are generally sorted according to known regime shifts. Years of regime shifts are shown in parentheses, since some stocks had more than one shift. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands, YFS = yellowfin sole, ATF = arrowtooth flounder, FH sole = flathead sole, POP = Pacific ocean perch, GT = Greenland turbot, Atka = Atka mackerel.

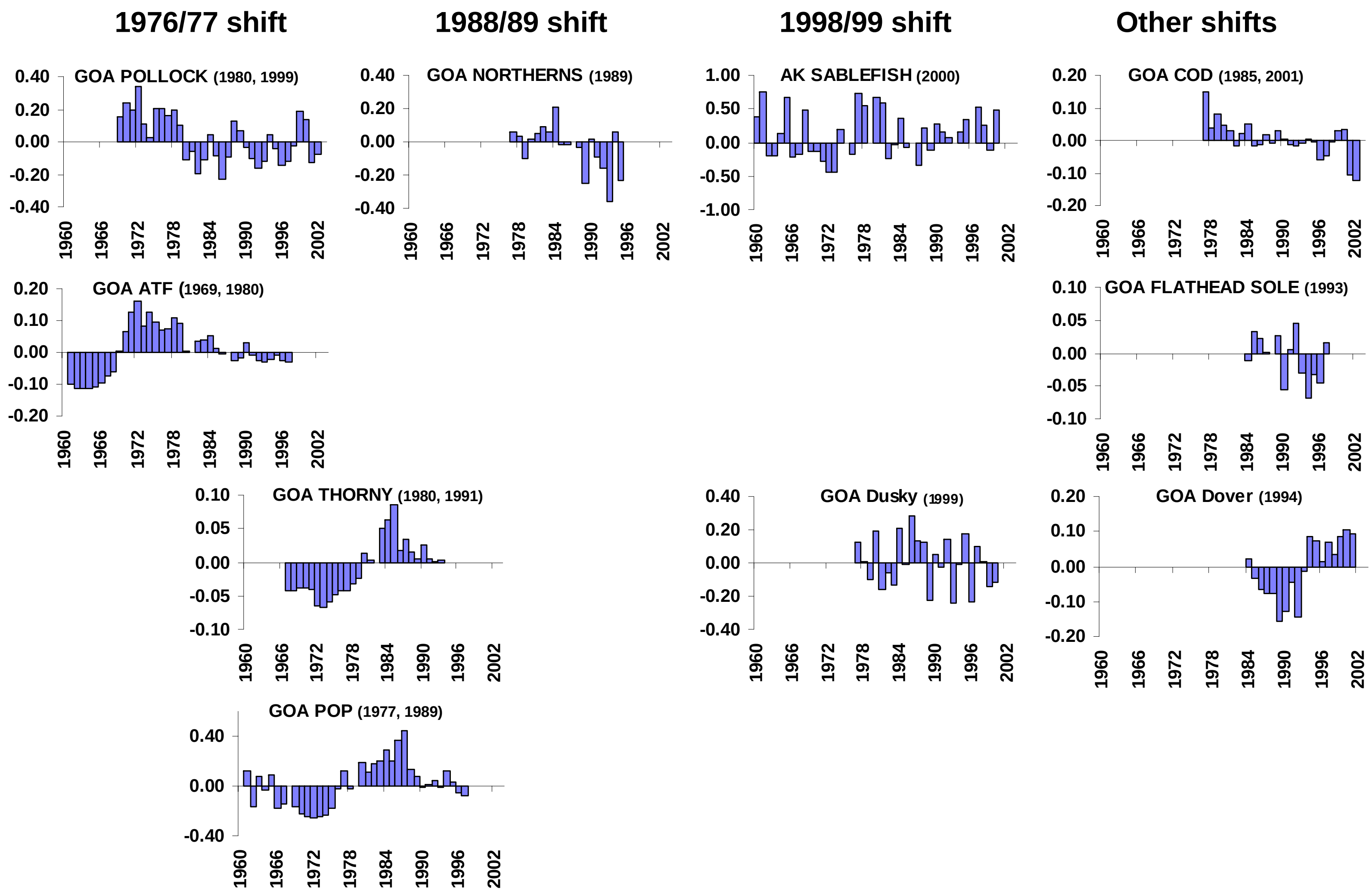

Figure 67. Median recruit per spawning biomass anomalies for GOA groundfish species assessed with age- or size-structured models and Thornyhead rockfish, 1960-2003. Stocks are generally sorted according to known regime shifts. Years of regime shifts are shown in parentheses, since some stocks had more than one shift. GOA = Gulf of Alaska, ATF = arrowtooth flounder, POP = Pacific Ocean perch, Sable = sablefish, Thorny = Thornyhead rockfish, Dusky = Dusky rockfish, Dover = Dover sole.

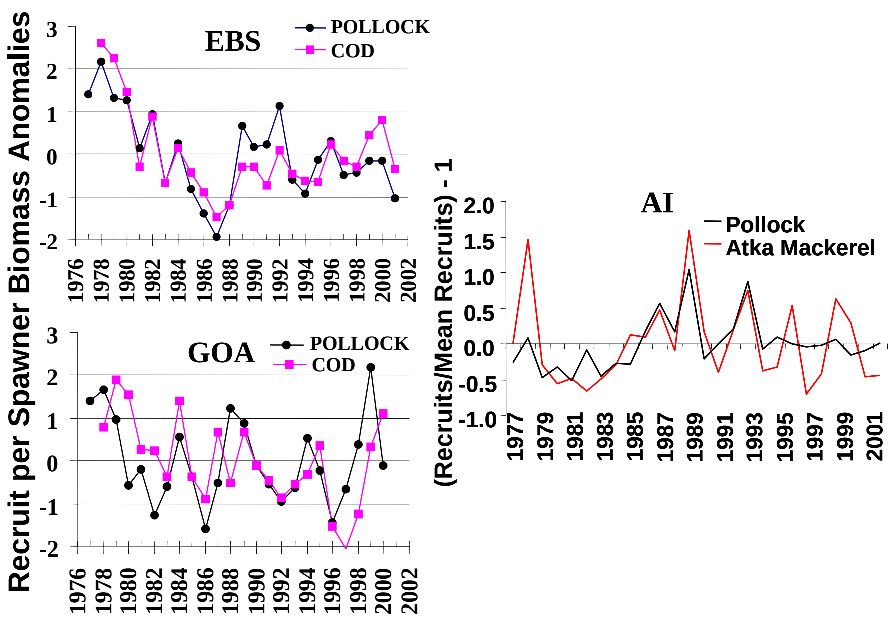

Figure 68. Recruit per spawner anomalies of BSAI and GOA pollock and cod and Aleutian Islands pollock and Atka mackerel (lagged back one year) recruits expressed as a proportion of mean recruits. Atka mackerel spawn in the summer and pollock spawn in the winter; therefore, the Atka mackerel were lagged by one year, to match the yearclasses that experienced similar conditions (modified from Barbeaux et al. 2003)

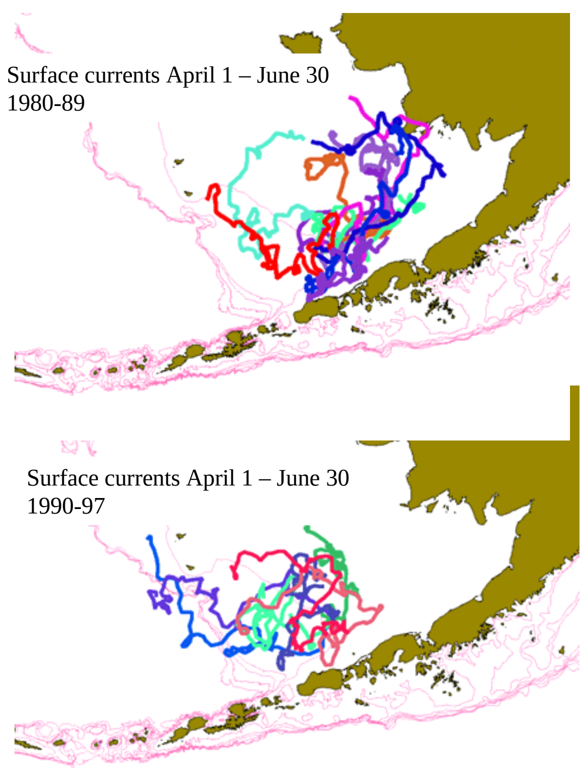

Figure 69. OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56° N, 164° W from April 1 – June 30 for the 1980's (upper panel) and 1990-96 (lower panel). Figure adapted from Wilderbuer et al. (2002).